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Research Article

Comparative Analysis of Xanthine Oxidase and Lipase Inhibition by Extracts from Different *Mesona chinensis* Cultivars

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Abstract

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This study investigated the differential inhibitory activities of five major Taiwanese *Mesona chinensis* Benth. cultivars ('Taoyuan No. 1', 'Taoyuan No. 2', 'Taoyuan No. 3', 'TARI No. 1', and 'Shuishang') against xanthine oxidase and lipase and explored their correlations with rosmarinic acid and caffeic acid content. The experimental results revealed significant inter-cultivar variations in the inhibitory activities against both enzymes among the different *M. chinensis* cultivars. 'TARI No. 1' exhibited the strongest xanthine oxidase inhibition (68.5%), while 'Taoyuan No. 2' (59.6%) and 'Taoyuan No. 3' (59.2%) showed greater lipase inhibitory effects. A high positive correlation (r = 0.735) was observed between the rosmarinic acid content of *M. chinensis* extracts and xanthine oxidase inhibition, suggesting rosmarinic acid as a potential indicator for this activity. Conversely, caffeic acid content showed a negative correlation (r = -0.807) with lipase inhibition, implying that other constituents in *M. chinensis* may contribute to lipase inhibitory activity. Notably, 'Taoyuan No. 3', a hybrid of 'Taoyuan No. 1' and 'Taoyuan No. 2', displayed enzyme inhibitory activity similar to that of 'Taoyuan No. 2', suggesting a potentially similar genetic expression pattern for the biosynthetic pathways of active components for enzyme inhibitory activity. These findings provide a basis for selecting specific *M. chinensis* cultivars for targeted metabolic regulation applications.

Key words: *Mesona chinensis*, Xanthine oxidase, Lipase, Enzyme inhibition activity, Constituent analysis.

INTRODUCTION

Hyperuricemia and hyperlipidemia are common metabolic disorders globally (Zhu *et al*. 2011; Husain *et al*. 2022; Zhang *et al*. 2022). Hyperuricemia is typically caused by abnormal uric acid metabolism. Excessive uric acid can form crystals in the joints and tissues, leading to gout attacks and increasing the risk of conditions such as kidney disease, fatty liver, and vascular inflammation (Choi & Ford 2007; Billiet *et al*. 2014). On the other hand, hyperlipidemia is mainly characterized by elevated levels of cholesterol and triglycerides in the blood,

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which can easily lead to atherosclerosis and arterial obstruction. This significantly increases the risk of cardiovascular diseases, subsequently raising the incidence of life-threatening conditions such as stroke and myocardial infarction (Hamaguchi *et al*. 2005; Bonora 2006). In addition, hyperuricemia and hyperlipidemia often co-occur and interact in metabolic disorders, further exacerbating metabolic disturbances and posing a greater threat to cardiovascular health and kidney function.

Xanthine oxidase (EC 1.17.3.2) and lipase (EC 3.1.1.3) play critical roles in the body's uric acid and fat metabolic pathways (Langin 2006; Battelli *et al*. 2018). Xanthine oxidase is a key enzyme in the human body for synthesizing uric acid. It can catalyze the oxidation of hypoxanthine to xanthine, and then catalyze the oxidation of xanthine to produce uric acid (Chen *et al*. 2016). Lipase, secreted by the pancreas, can catalyze the breakdown of dietary fats (mainly triglycerides) into monoglycerides and free fatty acids for absorption by the intestines (Liu *et al*. 2020). Finding inhibitors of these metabolic enzymes is a common way to develop drugs for metabolic syndrome. For example, allopurinol, a strong inhibitor of xanthine oxidase and a purine analog, is commonly used to treat hyperuricemia and gout (Hung *et al*. 2017). Another example is orlistat, a lipase inhibitor containing a β-lactone ring, which reduces dietary fat absorption and thus achieves weight loss (Richardson *et al*. 2008; Liu *et al*. 2020). These drugs play important roles in the treatment of metabolic diseases such as hyperuricemia and obesity, but their side effects cannot be ignored. For example, allopurinol may cause skin rashes and even severe allergic reactions, such as Stevens-Johnson syndrome (Hung *et al*. 2017). Common side effects of orlistat include oily stools and reduced absorption efficiency of fat-soluble vitamins (Liu *et al*. 2020). In contrast, natural extracts may have milder effects, less irritation to the gastrointestinal tract, and reduce the risk of allergies. This makes search for gentler enzyme inhibitors from natural crops essential.

Mesona chinensis Benth., which belongs to the Lamiaceae family, is a crop whose stems and leaves are rich in gelatin and possess a distinctive aroma. In Taiwan, *M. chinensis* is used to produce Mesona tea, a popular beverage in the summer. In the winter, *M. chinensis* is also prepared as a warm, comforting dessert known as grass jelly, making *M. chinensis* a favored crop year-round. Beyond its culinary uses, *M. chinensis* has traditional medicinal applications. Modern scientific research has further demonstrated the potential of *M. chinensis* extracts to regulate blood uric acid (Jhang *et al*. 2016; Chen *et al*. 2022) and blood lipids levels (Huang *et al*. 2016; Xiao *et al*. 2022). *M. chinensis* is abundant in phenolic acids (Yen & Hung 2000; Chusak *et al*. 2014; Huang *et al*. 2021). Previous studies have indicated that rosmarinic acid, a major component of *M. chinensis*, inhibits xanthine oxidase (Chen *et al*. 2022), while another component caffeic acid exhibits lipid-lowering activity (Xiao *et al*. 2022).

In Taiwan, *M. chinensis* is cultivated on approximately 100 ha, primarily across Taoyuan, Hsinchu, Miaoli, Yunlin, and Chiayi. The principal cultivars in Taiwan include 'Taoyuan No. 1', 'Taoyuan No. 2', 'Taoyuan No. 3', 'TARI No. 1', and 'Shuishang' (Fig. 1). 'Taoyuan No. 1', characterized by its high gelation properties, is the dominant cultivar in the Taoyuan, Hsinchu, and Miaoli. 'Taoyuan No. 2', a semi-erect variety, is grown in Yunlin, Chiayi, and Pingtung. 'Taoyuan No. 3' is a hybrid derived from a cross between 'Taoyuan No. 1' and 'Taoyuan No. 2'. 'TARI No. 1' is cultivated primarily in Miaoli and Hsinchu, while 'Shuishang' is the main cultivar in Shuishang, Chiayi. Currently, no studies have directly compared the metabolic enzyme inhibitory activities of these major *M. chinensis* cultivars. This study aims to investigate the xanthine oxidase and lipase inhibitory activities of five prominent Taiwanese *M. chinensis* cultivars. Using rosmarinic acid and caffeic acid as marker compounds, the study will also explore the correlation between enzyme inhibitory activity and the levels of these key components.

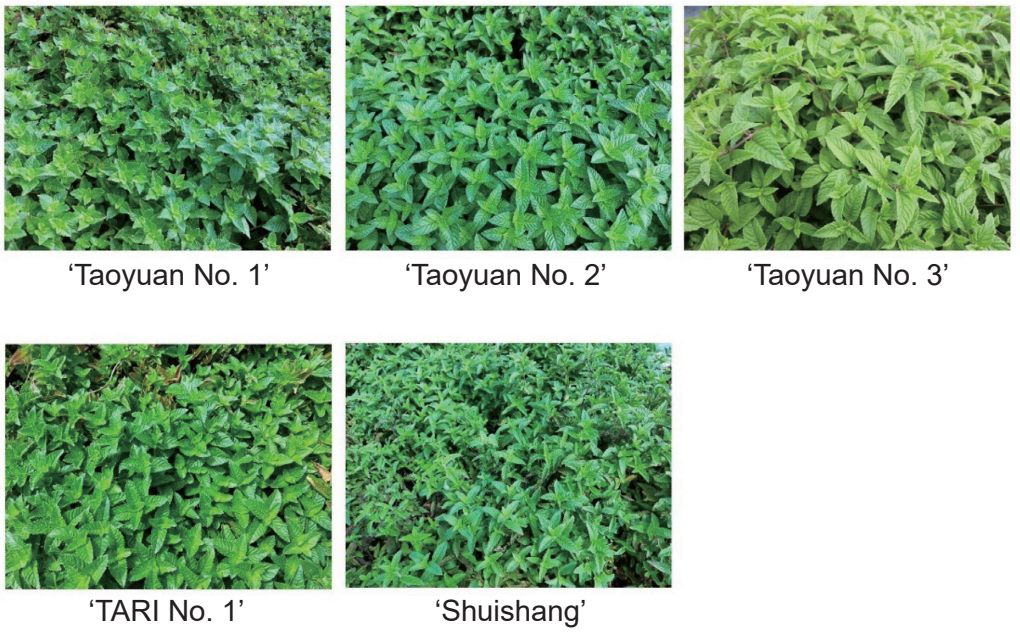

Fig. 1. Five principal *Mesona chinensis* cultivars in Taiwan.

MATERIALS AND METHODS

Plant materials

M. chinensis cultivars 'Taoyuan No. 1', 'Taoyuan No. 2', 'Taoyuan No. 3', and 'TARI No. 1' were collected from the Taoyuan District Agricultural Research and Extension Station, and 'Shuishang' was collected from Shuishang Township, Chiayi County. Stems and leaves were harvested together and sun-dried in the field for 3 d until the moisture content was reduced to below 10%. The dried material was stored at room temperature and remained stable for 6 mo prior to use.

Extraction procedure

The extraction procedure was modified from Jhang *et al*. (2016). Briefly, the dried *M. chinensis* material was ground using a tabletop mill machine (Chyun Tseh, Taichung, Taiwan) and passed through a 20-mesh sieve. The resulting powder was mixed with 50% ethanol at a ratio of 1:20 (w/v). The mixture was subjected to ultrasonic extraction for 1 h at 60℃ with an ultrasonic frequency of 60 Hz. Following extraction, the extract was centrifuged at 14,000× *g*. The supernatant was collected and used for subsequent experiments.

Xanthine oxidase inhibition assay

The xanthine oxidase inhibition assay was modified from Hung *et al*. (2017). Briefly, 100 µL aliquot of the test sample or compound was mixed with 30 µL of xanthine oxidase (X1875, Sigma-Aldrich, Burlington, MA, USA) solution (0.02 U mL^{-1} in 70 mM phosphate buffer, pH 7.5). The mixture was incubated at 25℃ for 15 min. The reaction was initiated by the addition of 70 µL of 150 µM xanthine. The mixture was then incubated in an ELISA reader at 25℃ for 30 min, and the absorbance at 290 nm was measured. The percentage inhibition was calculated according to the following formula: % Inhibition = [1 - (AS at 30 min − AS at 0 min)/(AC at 30 min − AC at 0 min)] × 100, where AS represented the absorbance of mixture which contained all solvents and sample, and AC was the control which contained

all solvent but the sample. The known xanthine oxidase inhibitor, Allopurinol, was used as a positive control. All experiments were performed in triplicate.

Lipase inhibition assay

The lipase inhibition assay was modified from Elbashir *et al*. (2018). Briefly, 50 μL of the test sample was added to 50 μL of lipase (L3126, Sigma-Aldrich, Burlington, MA, USA) solution at a concentration of 90 U mL^{-1} in 200 mM phosphate buffer, pH 7.4. This mixture was incubated at 25℃ for 10 min. Subsequently, 100 μL of 4-methylumbelliferyl oleate (19590, Cayman, Ann Arbor, MI, USA) at a concentration of 0.5 mM was added to the mixture. The mixture was then incubated in a fluorescence ELISA reader at 25℃ for 10 min, and the fluorescence at 460 nm (with an excitation wavelength of 355 nm) was measured. The percentage inhibition was calculated according to the following formula: % Inhibition = [1 - (FS at 10 min − FS at 0 min)/(FC at 10 min − FC at 0 min)] × 100, where FS represents the fluorescence readings of mixture, which contained all solvents and sample, and FC is the control which contained all solvent but the sample. The known lipase inhibitor orlistat was used as a positive control. All experiments were performed in triplicate.

Constituent analysis

Rosmarinic acid and caffeic acid in the *M. chinensis* extracts were quantified using Ultra-Performance Liquid Chromatography (UPLC). The analytical system consisted of an Acquity UPLC H-Class system (Waters Corp., Milford, USA) coupled with a photodiode array detector. The UPLC analysis procedure was modified from Zhang *et al*. (2019). Briefly, samples were filtered through a 0.22 μm syringe filter (Sartorius, Göttingen, Germany) before injection onto an ACQUITY UPLC® HSS T3 column (2.1 × 100 mm; 1.8 μm particle size; Waters, Milford, MA, USA). The column temperature was maintained at 40℃, and the flow rate was set at 0.3 mL min^{-1}. Solvent A consisted of acetonitrile/water/formic acid (2 : 97.9 : 0.1, v/v/v), and Solvent B consisted of acetonitrile/water/formic acid (99.9 : 0 : 0.1, v/v/v). The following gradient elution program was employed: 0 min (92% A and 8% B); 3 min (70% A and 30% B); 7 min (70% A, 30% B); 9 min (0% A, 100% B); 13 min (0% A, 100% B); 14 min (92% A, 8% B); and 15 min (92% A and 8% B). The detection wavelengths were set at 330 nm for rosmarinic acid and 323 nm for caffeic acid, corresponding to their respective wavelengths of maximum absorbance. Calibration curves were generated using a series of standard solutions at varying concentrations. The concentrations of caffeic acid and rosmarinic acid in the extracts were then determined using the respective calibration curves. All samples were measured in triplicate.

Statistical analysis

Differences between groups were analyzed by one-way analysis of variance (ANOVA) using CoStat version 6.400 (CoHort Software, Pacific Grove, CA, USA). If significant differences were detected ($P < 0.05$), Tukey's honestly significant difference (HSD) test was used for post hoc comparisons. Correlation analysis was carried out by SigmaPlot 12.0 (Graffiti LLC, Palo Alto, CA, USA), and significance was determined by a $P < 0.05$.

RESULTS

Quantification of marker compounds

In this study, 50% ethanol extracts from five *M. chinensis* cultivars were subjected to quantitative analysis using UPLC of two marker compounds, caffeic acid and rosmarinic acid (Fig. 2). The results revealed variations in the levels of these marker compounds among the cultivars. For rosmarinic acid content, 'Shuishang' had the highest concentration (80.34 ± 1.65 mg g^{-1}), followed by 'TARI No. 1' (57.76 ± 1.50 mg g^{-1}). 'Taoyuan No. 2' (19.70 ± 0.07 mg g^{-1}) and 'Taoyuan No. 1' (18.37 ± 0.23 mg g^{-1}). 'Taoyuan No. 3' had the lowest rosmarinic acid content (13.20 ± 0.08 mg g^{-1}) (Table 1).

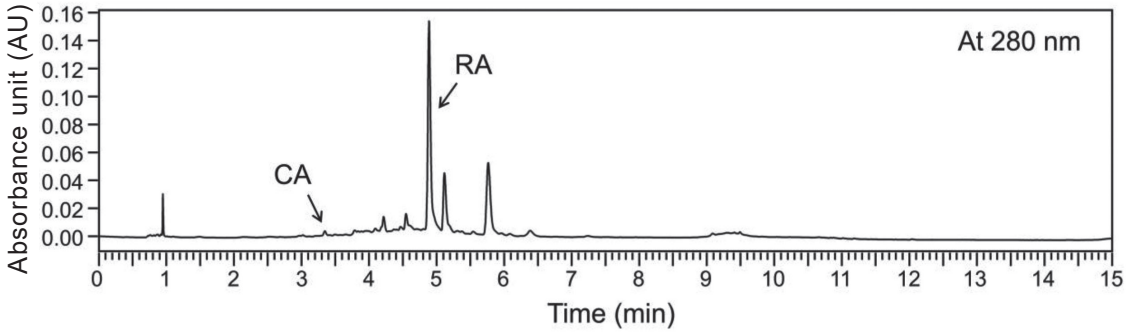

Fig. 2. Ultra-performance liquid chromatography (UPLC) fingerprint at 280 nm of 'Shuishang' extract. RA indicates rosmarinic acid. CA indicates caffeic acid.

Table 1. Analysis of caffeic acid and rosmarinic acid content of extracts from different cultivars of *Mesona chinensis*. Data were expressed as mean ± standard deviation (Mean ± *SD*)

Cultivars	Caffeic acid content (mg g^{-1})	Rosmarinic acid content (mg g^{-1})
'Taoyuan No. 1'	0.13 ± 0.00 bc[z]	18.37 ± 0.23 c
'Taoyuan No. 2'	0.14 ± 0.00 b	19.70 ± 0.07 c
'Taoyuan No. 3'	0.11 ± 0.00 d	13.20 ± 0.08 d
'TARI No. 1'	0.13 ± 0.00 c	57.76 ± 1.50 b
'Shuishang'	0.17 ± 0.01 a	80.34 ± 1.65 a

[z] The difference between means for variables sharing the same letter is not statistically significant (one-way analysis of variance (ANOVA), Tukey's honestly significant difference (HSD) test, $P < 0.05$).

Regarding caffeic acid, 'Shuishang' also exhibited the highest concentration (0.17 ± 0.01 mg g^{-1}), followed by 'Taoyuan No. 2' (0.14 ± 0.00 mg g^{-1}). 'Taoyuan No. 1' (0.13 ± 0.00 mg g^{-1}) and 'TARI No. 1' (0.13 ± 0.00 mg g^{-1}). 'Taoyuan No. 3' had the lowest caffeic acid content (0.11 ± 0.00 mg g^{-1}) (Table 1).

Xanthine oxidase inhibition activity

The inhibitory effects of the 50% ethanol extracts from the five *M. chinensis* cultivars on xanthine oxidase activity were evaluated *in vitro* at a concentration of 100 μg mL^{-1}. The results indicated that 'TARI No. 1' exhibited the highest xanthine oxidase inhibitory activity, significantly greater than the other cultivars, with an inhibition rate of 68.5 ± 1.0%. 'Shuishang' and 'Taoyuan No. 1' followed, with inhibition rates of 61.7 ± 2.1% and 58.9 ± 3.1%, respectively. 'Taoyuan No. 2' and 'Taoyuan No. 3' showed lower inhibition rates, significantly lower than the other cultivars, at 49.6 ± 1.3% and 49.4 ± 2.0%, respectively (Fig. 3). The inhibition rate of the positive control Allopurinol (4 μM) was 91.5 ± 0.4%.

Lipase inhibition activity

The inhibitory effects of 50% ethanol extracts from five *M. chinensis* cultivars on lipase activity were evaluated *in vitro*. The tested samples included extracts from 'Taoyuan No. 1', 'Taoyuan No. 2', 'Taoyuan No. 3', 'TARI No. 1', and 'Shuishang', all at a concentration of 100 μg mL^{-1}. The results revealed that 'Taoyuan No. 2', 'Taoyuan No. 3', and 'Taoyuan No. 1' exhibited higher lipase inhibitory activity, with inhibition rates of 59.6 ± 2.2%, 59.2 ± 4.2%, and 54.1 ± 1.1%, respectively. 'TARI No. 1' showed slightly lower inhibition (50.4 ± 4.7%), but the difference was not statistically significant compared to 'Taoyuan No. 3' and 'Taoyuan No. 1'. 'Shuishang' demonstrated the lowest

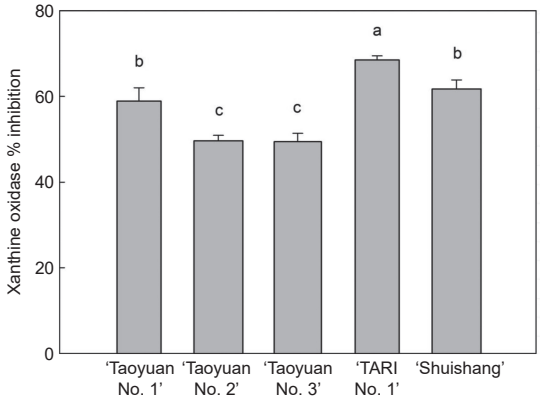

Fig. 3. Analysis of xanthine oxidase inhibitory activity in extracts from five *Mesona chinensis* cultivars (n = 3). The difference between means for variables sharing the same letter is not statistically significant (one-way analysis of variance (ANOVA), Tukey's honestly significant difference (HSD) test, $P < 0.05$).

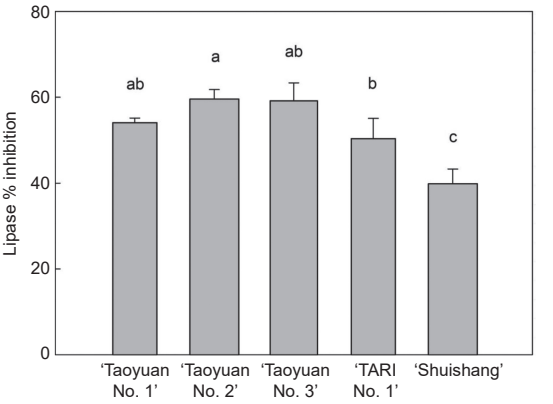

Fig. 4. Analysis of lipase inhibitory activity in extracts from five *Mesona chinensis* cultivars (n = 3). The difference between means for variables sharing the same letter is not statistically significant (one-way analysis of variance (ANOVA), Tukey's honestly significant difference (HSD) test, $P < 0.05$).

inhibitory effect, significantly lower than the other cultivars, with an inhibition rate of 39.9 ± 3.4% (Fig. 4). The inhibition rate of the positive control orlistat (20 μM) was 60.2 ± 6.9%.

Correlation analysis

The correlation analysis revealed a highly positive correlation between rosmarinic acid content and xanthine oxidase inhibitory activity in *M. chinensis* extracts, with a correlation coefficient (r) of 0.735 (Fig. 5A). This correlation was statistically significant, as indicated by a P-value of less than 0.05 ($P < 0.05$). Furthermore, a highly negative correlation was observed between caffeic acid content and lipase inhibitory activity, with r = -0.807 (Fig. 5B). This negative correlation was also statistically significant ($P < 0.05$).

DISCUSSION

Metabolic regulatory applications of different *M. chinensis* cultivars

While many natural compounds have been reported to possess enzyme inhibitory activities and may serve as potential alternatives to synthetic drugs, their application often faces challenges, such as inconsistent effects due to variations in plant sources (Wu *et al*. 2017; Guo *et al*. 2018; Wang *et al*. 2021). Therefore, systematically evaluating the enzyme inhibitory activities from well-defined plant sources, such as different cultivars, is crucial for identifying more reliable and effective natural metabolic regulators. This study, by comparing the xanthine oxidase and lipase inhibitory activities of five major *M. chinensis* cultivars in Taiwan, aims to provide a more precise basis for developing *M. chinensis*-based metabolic regulatory applications and highlights the differences in activity among cultivars, which can facilitate a more targeted selection and utilization of *M. chinensis* resources for metabolic regulatory applications.

The experimental results demonstrated variations in xanthine oxidase and lipase inhibitory activities among five *M. chinensis* cultivars (Figs. 3 and 4), suggesting the potential to recommend specific cultivars for metabolic regulation applications. In previous studies, 50% ethanol has been identified as the optimal ethanol ratio for extraction solvent to maximize total phenolic content from *M. chinensis* (Jhang *et al*. 2016). Notably, 50% ethanol extracts of *M. chinensis* have also demonstrated favorable xanthine oxidase inhibitory activity,

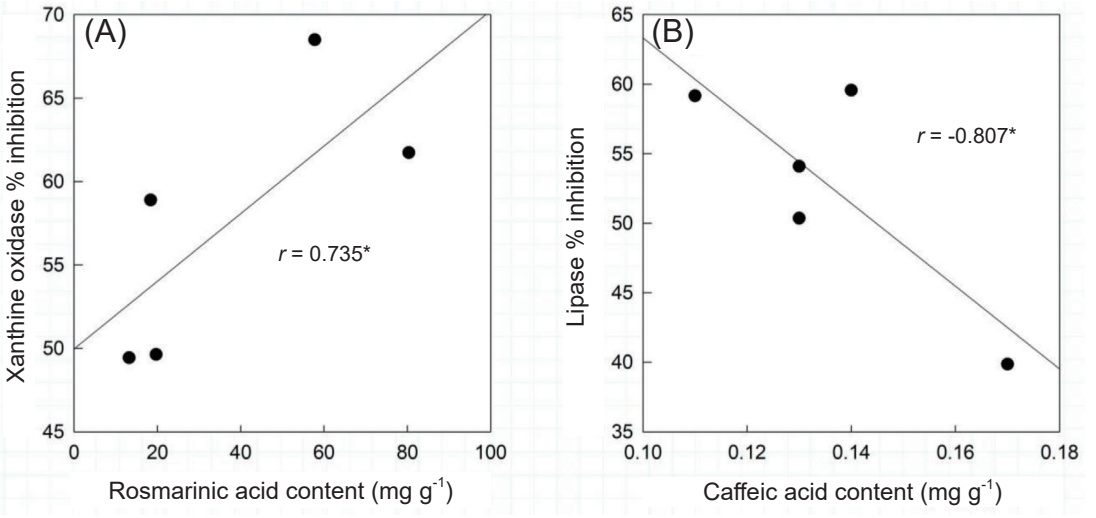

Fig. 5. Relationships in *Mesona chinensis* extracts between (A) rosmarinic acid content and xanthine oxidase inhibitory activity and (B) caffeic acid content and lipase inhibitory activity. The correlation coefficients (r) are annotated on the figure. * indicates significance at $P < 0.05$.

with an IC_{50} of 17.3 ± 2.2 μg mL^{-1} (compared to allopurinol, a positive control, at 1.6 μg mL^{-1}) (Chen *et al*. 2022). Furthermore, when compared to hyperuricemic ICR mice, the 50% ethanol extracts of *M. chinensis* significantly reduced serum uric acid levels in the treatment group (Chen *et al*. 2022), indicating the potential of 50% ethanol extracts of *M. chinensis* for uric acid lowering both *in vitro* and *in vivo*. Therefore, in this comparative study of cultivars in xanthine oxidase inhibition assay, we consistently used 50% ethanol extracts to ensure that variations in observed activities were attributable to cultivar differences rather than extraction efficiency. 'TARI No. 1' exhibited superior performance in xanthine oxidase inhibition (68.5% inhibition rate) (Fig. 3), indicating its potential for uric acid metabolism regulation. Other *M. chinensis* cultivars, such as 'Shuishang' and 'Taoyuan No. 1', although displaying slightly lower xanthine oxidase inhibition activity than 'TARI No. 1', still maintained inhibition rates above 50% (61.7% and 58.9% inhibition rates, respectively) (Fig. 3), suggesting their potential for uric acid modulation as well.

In contrast, the relationship between 50% ethanol extracts of *M. chinensis* extracts and lipase inhibition is still unclear. Although 50% ethanol extracts of *M. chinensis* have been found to ameliorate hyperlipidemia in high-fat diet-induced mice and rats (Yang *et al*. 2024), we found no literature exploring the lipase inhibitory activity of *M. chinensis* extracts. Therefore, this study may be the first to investigate the inhibitory effect of *M. chinensis* extracts on lipase, providing insight into the potential mechanisms by which *M. chinensis* extracts improve hyperlipidemia. Among all *M. chinensis* cultivars, 'Taoyuan No. 2' and 'Taoyuan No. 3' exhibited superior lipase inhibition (59.6% and 59.2% inhibition rates, respectively) (Fig. 4), suggesting their potential for blood lipid control and weight management. 'Taoyuan No. 1' and 'TARI No. 1' showed slightly lower lipase inhibition rates (54.1% and 50.4% inhibition rates, respectively) (Fig. 4), but their inhibition rates remained above 50%, suggesting their potential to also influence blood lipid levels. 'Shuishang' exhibited the lowest lipase inhibition effect (39.9% inhibition rate) (Fig. 4), suggesting it may not be suitable for blood lipid regulation.

Given that *M. chinensis* extracts have been

shown to have hypouricemic and hypolipidemic effects in animal models (Jhang *et al*. 2016; Xiao *et al*. 2022; Yang *et al*. 2024), the observed *in vitro* enzyme inhibitory activities provide mechanistic support for their potential in metabolic regulation. The enzyme inhibitory activities of *M. chinensis* extracts may also indicate their potential *in vivo* efficacy in reducing uric acid or lipid levels. Future studies evaluating the *in vivo* effects of extracts from different *M. chinensis* cultivars in animal models or human subjects are warranted. The inhibitory activities of different *M. chinensis* cultivar extracts against various enzymes show discrepancies. For example, 'Taoyuan No. 2' and 'Taoyuan No. 3' exhibited the lowest xanthine oxidase inhibition activity but the highest lipase inhibition activity (Figs. 3 and 4). Therefore, suitable *M. chinensis* cultivars may vary for different metabolic conditions. Overall, different *M. chinensis* cultivars can be selectively applied to regulate lipid or uric acid metabolism. For complex metabolic syndromes, extracts from different cultivars may be combined to form multifunctional metabolic regulators, achieving more comprehensive health management effects.

Relationship between contents of marker compounds and enzyme inhibitory activity

Previous studies utilizing mass spectrometry have identified rosmarinic acid as a major component from the *M. chinensis* fraction exhibiting high xanthine oxidase inhibitory activity (Chen *et al*. 2022). Rosmarinic acid is a natural polyphenolic compound widely found in Lamiaceae plants, including *M. chinensis*, rosemary (*Rosmarinus officinalis* L.), mint (*Mentha spicata* L.), and perilla (*Perilla frutescens* (L.) Britton) (Takano *et al*. 2004; Shekarchi *et al*. 2012). Rosmarinic acid possesses potent antioxidant capabilities, effectively scavenging free radicals. Moreover, rosmarinic acid exhibits xanthine oxidase inhibitory activity (Chen *et al*. 2022; Tipsuwan *et al*. 2024), suggesting its potential application in preventing and treating hyperuricemia and gout. Our results demonstrated that *M. chinensis* indeed contains abundant rosmarinic acid (13.20–80.34 mg g^{-1}) (Table 1). The variations in rosmarinic acid content among cultivars also indicate potential differences in secondary metabolite biosynthesis and functional activity across these varieties. A highly positive correlation was observed between the rosmarinic acid content and the xanthine oxidase inhibition rate (Fig. 5A). For example, 'Shuishang' (80.3 mg g^{-1}) and 'TARI No. 1' (57.8 mg g^{-1}), had the highest rosmarinic acid contents and also exhibited stronger inhibitory effects on xanthine oxidase, with inhibition rates of 61.7% and 68.5%, respectively (Table 1 and Fig. 3). This supports the potential role of rosmarinic acid in inhibiting xanthine oxidase, consistent with its known anti-hyperuricemic properties.

Caffeic acid is considered as an effective lipase inhibitor (Buchholz & Melzig 2015). However, in our results, a negative correlation between caffeic acid content and lipase inhibitory activity was found in the *M. chinensis* extracts. For instance, 'Shuishang' had the highest caffeic acid content (0.17 mg g^{-1}), but showed the lowest lipase inhibitory effect (39.9%). Conversely, 'Taoyuan No. 2' (0.14 mg g^{-1}) and 'Taoyuan No. 1' (0.13 mg g^{-1}), which had relatively lower caffeic acid contents, performed well in the lipase inhibition assay, with inhibition rates of 54.1% and 59.6%, respectively (Table 1 and Fig. 4). The observed negative correlation between caffeic acid content and lipase inhibitory activity (Fig. 5B) in our *M. chinensis* extracts suggests that under the 50% ethanol extraction conditions, caffeic acid may not be the primary component responsible for lipase inhibition, or its effects might be masked by other compounds present at higher concentrations. This inverse relationship could be attributed to the relatively low concentration of caffeic acid in the 50% ethanol extracts. While 50% ethanol extracts exhibited high total phenolic content (Jhang *et al*. 2016), the concentration of caffeic acid decreases in fractions with higher ethanol concentrations

(Xiao *et al*. 2022). Other compounds in *M. chinensis* related to lipid metabolism, such as kaempferol-7-O-glucoside, rosmarinic acid-3-O-glucoside, and apigenin-3-O-rutinoside (Xiao *et al*. 2022), may also play a role in lipase inhibition. Further investigation is needed to explore these potential candidates.

Enzyme inhibition activity between hybrid cultivar and parental lines

'Taoyuan No. 3', a hybrid cultivar derived from 'Taoyuan No. 1' and 'Taoyuan No. 2', exhibited intermediate lipase and xanthine oxidase inhibitory activities compared to its parent cultivars. Notably, the inhibitory activities against both enzymes of 'Taoyuan No. 3' were closer to those of 'Taoyuan No. 2' (Figs. 3 and 4). This observation aligns with the UPLC fingerprint profiles, which also revealed greater similarity between 'Taoyuan No. 3' and 'Taoyuan No. 2' (data not shown). These findings suggest a potential inheritance pattern where 'Taoyuan No. 3' may be inherited a higher proportion of genetic determinants related to the biosynthesis of the active components from 'Taoyuan No. 2'. Further investigation about the specific components contributing to these differences in enzyme inhibition, as well as the underlying genetic mechanisms, could provide valuable insights for future breeding of *M. chinensis*.

CONCLUSIONS

In summary, rosmarinic acid appears to play a crucial role in the xanthine oxidase inhibitory activity of *M. chinensis* extracts. While caffeic acid has been reported in the literature to possess lipase inhibitory activity, its levels in the *M. chinensis* extracts did not exhibit a significant positive correlation with lipase inhibition. This is likely due to the relatively low caffeic acid content in the *M. chinensis* extracts, suggesting that lipase inhibition activity may depend more on other components. The differences in component composition among the various *M. chinensis* cultivars result in varying potentials for metabolic enzyme inhibition. This provides important information for selecting appropriate *M. chinensis* cultivars for future metabolic regulatory applications.

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不同仙草品種萃取物對黃嘌呤氧化酶與脂肪酶抑制活性的比較分析

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摘要

洪子桓、張家華、陳秋樺、龔財立、楊颺。2025。不同仙草品種萃取物對黃嘌呤氧化酶與脂肪酶抑制活性的比較分析。台灣農業研究 74(3):291–301。

本研究旨在探討臺灣 5 種主要仙草 (*Mesona chinensis* Benth.) 品種 (「桃園 1 號」、「桃園 2 號」、「桃園 3 號」、「農試 1 號」及「水上種」) 對黃嘌呤氧化酶 (xanthine oxidase) 與脂肪酶 (lipase) 的抑制活性差異，並探究其與迷迭香酸 (rosmarinic acid) 與咖啡酸 (caffeic acid) 含量的相關性。實驗結果顯示，不同仙草品種間對 2 種酵素的抑制活性存在顯著的品種間差異。其中，「農試 1 號」表現出最強的黃嘌呤氧化酶抑制活性 (68.5%)，而「桃園 2 號」(59.6%) 與「桃園 3 號」(59.2%) 則對脂肪酶展現較佳的抑制效果。仙草萃取物中迷迭香酸含量與黃嘌呤氧化酶抑制率呈現高度正相關 (r = 0.735)，顯示迷迭香酸可能適合作為黃嘌呤氧化酶抑制活性的指標成分。相反地，咖啡酸含量與脂肪酶抑制活性呈現負相關 (r = -0.807)，暗示仙草中其他成分可能影響脂肪酶抑制活性。值得注意的是，作為「桃園 1 號」與「桃園 2 號」雜交後代的「桃園 3 號」，其酵素抑制活性與「桃園 2 號」相似，這暗示「桃園 3 號」酵素抑制活性成分的生物合成途徑可能展現與「桃園 2 號」更為接近的遺傳表達模式。本研究結果為未來選擇合適的仙草品種應用於目標代謝調節提供了依據。

關鍵詞：仙草、黃嘌呤氧化酶、脂肪酶、酶抑制活性、成分分析。

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